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A Review on processing and mechanical performance of natural fiber composites

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Abstract

Natural fiber composite material is one of the emerging field in material engineering. A lot of research is going on to find natural fibers and their potential for large number of application. There are many techniques through which we can extract natural fibers from parent plant. These extracted fibers has to be embedded into polymer matrix by different processing methods. Selection of processing method depend upon type of polymer matrix, type of natural fiber and desired mechanical properties. The method of natural fiber processing greatly affect the resulted properties of fabricated composite. Along processing methods there are different factors which are responsible for influencing mechanical properties of natural fiber composites. This review paper focus on different natural fiber processing techniques and mechanical performance of natural fiber composites.

Keywords*—Natural Fiber Composite; Resign Transfer Molding.*

INTRODUCTION

Composites are multifunctional material systems that provide characteristics not obtainable from any individual material. These are the structures which are made by physically combining two or more materials different in composition and characteristics. Due to increase in population natural resources are continuously exploited substantially as an alternative to synthetic materials. Therefore use of natural fibers for the reinforcement of the composites has received increasing attention. Natural fibers have many advantages over synthetic fibers. Nowadays various types of natural fibers have been investigated for use in composites including flax, hemp, kenalf, ramie, banana fiber, grewia optiva etc. Due to necessity for ecofriendly materials, natural fiber composites are getting the attention which was earlier shifted to synthetic products. The first known utilization of natural fiber composites was straw reinforced clay for bricks and pottery [1]. As synthetic fiber composite materials such as glass fibers, carbon fibers and aramid are high performance materials but these are less biodegradable and are sourced from nonrenewable resources. Therefore the use of natural fibers may bring environmental benefits for coming years. So it is very important to now the potential of natural fiber and bring them for different applications. When natural fibers extracted from resources cannot be used directly because they do not give optimum qualities. So fibers are either chemically treated or either physically treated to enhance structural properties.

START COMMON NATURAL FIBERS

BANANA FIBER Banana fiber is a lignocellulosic fiber which is obtained from the pseudo stem of banana plant, it is a bast fiber having great mechanical properties. Plant strands are sclerenchymatous cells with lignified cell dividers having a thin lumen in cross segment [2]. Natural fibers have many several advantages over synthetic fibers such as low density, appropriate stiffness, good mechanical properties and renewability. Banana fibers are used for in composite material, paper and craft work industry. Because of its water proof characteristics it has been used in packaging and building material [3]. India is large producer of banana, after extracting fruits from banana plant a large amount of residue is left over. It has been found that yearly 17000 tons of fibers are extracted from these residues [4]. Banana fiber has been used by many researcher in different polymers to enhance the properties of the polymer. Effect of banana fiber length (10 mm to 40 mm) and content (from 20% to 50%) on the mechanical properties and aging characteristics of polyester composites reinforced with these fibers has been investigated [5]. Banana fiber/ polyester composites showed highest tensile, flexural, and impact strength with 30 mm long fibers and at 40% fiber loading. To modify properties and limits hydrophobicity banana fibers are chemically treated.

KENALF FIBER: Kenalf whose scientific name is Hibiscus cannabinus is made up from inner woody core and an outer fibrous bark surrounding the bark. Kenalf has been used from ancient time to produce twin, rope and sackcloth. Now a day's kenalf is being used in building material, paper products, absorbents and composite industry. Kenalf fiber has superior tensile as well as flexural strength which attract its use in automobile and aerospace industry. Kenalf is used in many polymer composites which is an alternative to glass fiber. Some of its properties in terms of cost, density, renewability, recyclability, abrasiveness, and biodegradability makes it comparable with other traditional reinforcements. The efficiency of natural fiber composites depend upon the adhesive force between fiber and polymer matrix. Kenalf fibers has been treated before adding them in polymers in order to get desired mechanical properties. In a study alkali treated kenalf fiber for different percentages, (5–25% weight fraction) were used as reinforcement in polyester matrix [6]. By some researcher polyester resin was mixed with a toughening agent, liquid natural rubber (LNR), to examine its effect on impact properties of composites. Results indicated that impact, flexural, and fracture toughness properties were improved significantly at 20% fiber weight fraction. Composites containing treated kenalf fiber had superior properties than those which were not treated.

JUTE FIBER: After cotton jute is second in terms of usage, production, consumption and usage. Jute is a bast fiber like flax and hemp and stems are processed in same way. Jute fibers varies in a length of 1m to 4m of silky, lustrous and brown in color. The fibers can be extracted by either biological or chemical retting processes. Given the expense of using chemicals to strip the fiber from the stem biological processes are more widely practices. Biological retting can be done by either by stack, steep and ribbon processes which involve different techniques of bundling jute stems together and soaking in water to help separate the fibers from the stem before stripping. Jute fibers has great important role composite industry. Many researcher has used jute fibers in thermoplastic as well as thermoset plastics. Jute fibers of length 5 –

6 mm in polyester and epoxy resin to study mechanical properties [7]. The results show that the jute reinforced epoxy composite exhibited better mechanical properties than Jute-polyester composite.

SISAL: Sisal fiber is usually obtained from the leaves of the Agave sisalana plant, which is largely available in tropical countries. The surface of this fiber must be chemically modified in order to make it more compatible with the polymeric matrix. Taking into consideration that fiber–matrix interface determines the mechanical properties of the composites, several experimental techniques including pull-out tests, fiber fragmentation tests, and fiber push-out have been used to characterize interface properties. The effects of fiber chemical treatment and manufacturing method on tensile, flexural, impact, hardness, and water absorption properties of sisal/polyester composites and the resulted fracture mechanisms and interface properties are discussed. A sisal plant produces about 200–250 leaves and each leaf contains 1000–1200 fiber bundles, which is composed of 4% fiber, 0.75% cuticle, 8% dry matter, and 87.25% water. So, normally a leaf weighing about 600 gm yields about 3% by weight of fiber with each leaf containing about 1000 fibers.

COIR FIBER: Coir is a versatile natural fiber extracted from the husk of coconut fruit. They are made up of small threads each less than 0.05-inch (1.3 mm) long and 10 to 20 micrometers in diameter [8]. The coconut refers to the entire fruit which has a hard inner shell and outer fibrous material. The fibrous layers are separated either by manual de-husking or through a crushing machine [9]. Coir fibers are used to make ropes, door mate, mattresses and brushes. Among all natural fibers it has maximum lignin. Coir has the quality of waterproof and absorbs less quantity of salt water. These fibers can be stretched beyond its elastic limit without rupture due to a micro-fibrillar spiral angle. Water absorption of coir fiber was explored by several researchers as it possesses the lowest moisture absorption among plant fibers [10].

PROCESSING OF NATURAL FIBER REINFORCED COMPOSITE

The processing methods used for natural fiber composites are comparable with the methods used for fabricating composites. Being availability of different processing techniques natural fibers are not so easy to add efficiently into the matrix. Natural fibers possess low permeability lower then glass fiber mats means high volume fraction are preventive to fiber impregnation by traditional techniques

RESIGN TRANSFER MOLDING This process yields good laminate compression, a high glass-to-resin ratio and high strength-to-weight characteristics. RTM parts have two finished surfaces. Reinforcement mat or woven roving is placed in the mold, which is then closed and clamped. Catalyzed, low-viscosity resin is pumped in under pressure, displacing the air and venting it at the edges until the mold is filled. Molds for this low-pressure system are usually made from composite or nickel shell-faced composite construction. RTM is mainly used for continuous-strand mat and woven roving as well as discontinuous dispersed lignocellulose fibers [11]. RTM processing technique ensure good control over the fiber orientation. This process is suited for mass production of 100 to 10,000 units/year of high-quality composite fiberglass or fiber-reinforced plastic parts. It is recommended for products that require high strength-to-weight requirements. Tooling used in this process can be made from various materials including aluminum, nickel shell, mild steel and polyester.

PREPAG DEVELOPMENT Prepregs can be created for natural fibers in many ways. The most common method is by sheet molding compound (SMC) [12]. SMC can be performed in normal composite production and care must be taken to prevent excessive moisture absorption after processing. To overcome this problem prepregs are stored in air tight bags. Unidirectional Prepregs can also be obtained by drum winding of fibers and resin. Sometimes fiber tension and yarn impregnation can make this process challenging [13].

PULTRUSION Pultrusion is a process which is used to produce continuous and constant-cross-section composites. It has been widely used in producing unidirectional composites with natural fiber reinforcement with flax, hemp, kenalf, and jute fibers in yarn forms. Because the methods relies on the pulling of continuous roving through a resin bath/impregnator, care must be taken in the production using natural fibers due to their yarns low pull strength. Pull speeds have been limited to 100–200 mm/min which is low compared to the pull speeds used during glass fiber processing [14].

COMPRESSION MOLDING Compression molding is a common processing technique used for natural fiber composite fabrication because of its simplicity and versatility. In this process pre-mixing of short fibers into resins are done and then using heated or non-heated compression to achieve full impregnation. With different pressure applied, the fiber volume fraction of the composite can be controlled and yields of 60–65% are possible. In addition, composite parts with a number of complex geometries and fiber orientations are possible, although the size of the composites yielded is limited by the size of presses. Furthermore, the processing method is both labor intensive and brings processors into contact with the liquid resins and their volatile emissions.

PROCESSING OF NATURAL FIBER REINFORCED COMPOSITE

Our main purpose in composite material is to prove better mechanical properties to the fabricated material. There are many factors which are responsible to alter mechanical properties of composite material. So we should take care all the factors which affects the mechanical performance of material. Some major factors which affects mechanical performance of natural fiber composite.

MATRIX MATERIAL Matrix selection is important criterion to obtain desired mechanical properties. It acts as a barrier against adverse environment and protects fibers from abrasion and transfer load to the fiber. Polymeric matrixes are widely used in natural fiber composite which are processed at low temperature. Both thermoset and thermo plastic polymers have been used for matrix are used with natural fibers [15]. Since natural fibers has limitation of not working at elevated temperature, so polymer is selected on the basis of properties of natural fiber. Sometimes these are processed at high temperature for short period of time [16]. It should be noted that the thermoplastics constitute the most common thermoplastics consumed by the plastics industry and far outweighs the use of any other thermoplastic matrices generally used. Indeed Polypropylene and polyethylene are the two most commonly adopted thermoplastic matrices for Natural Fiber Composites. The main thermosets used are unsaturated polyester, epoxy resin and phenol formaldehyde resins. Thermoplastics are capable of being repeatedly softened by the application of heat and hardened by cooling and have the potential to be the most easily recycled, which has seen them most favored in recent commercial uptake, whereas better realization of the fiber properties are generally achieved using thermosets [17].

NATURAL FIBER Fiber type is mainly categorized on the basis of its origin: plant, animal or mineral. Cellulose is the main structural component for plant fibers, whereas animal fibers mainly consist of protein. Although mineral-based natural fibers exist within the asbestos group of minerals and were once used extensively in composites, these are now avoided due to associated health issues. Generally much higher strengths and stiffness are obtainable with the higher performance plant fibers than the available animal fibers. An exception to this is silk, which can have very high strength, but is relatively expensive, has lower stiffness and is less readily available [18]. Higher performance can be obtained with fibers having higher cellulose content and with cellulose micro fibrils aligned more in the fiber direction. The properties of natural fibers depends on chemical composition and structure, which relate to fiber type as well as growing conditions, harvesting time, extraction method, treatment and storage procedures. Strength of fabricated composite has been seen to reduce by 15% over 5 days after optimum harvest time [19].

FIBER DISTRIBUTION Fiber distribution has is a major factor influencing the properties of natural fiber composites. Good fiber distribution helps to obtain good interfacial bonding, reducing voids by ensuring that fibers are fully covered by the matrix. Distribution can be affected by different process parameters such as temperature and pressure. By some researcher additives such as stearic acid have been used in Polyethylene and Polyester to modify dispersion to increase adhesive force to enhance fiber matrix interaction. Fiber modification using grafting can also can be applied but it is more expensive [20]. The best mechanical properties can be obtained for when the fiber is aligned in a direction parallel to the applied load. However it is not so easy to get alignment with natural fibers than for continuous synthetic, by injection molding alignment is achieved. For higher degrees of fiber alignment, long natural fiber can be carded and placed manually in sheets without matrix impregnation.

ADHESIVE STRENGTH Adhesive strength between fiber and matrix decide the mechanical properties of composites. Since stress is transferred between matrix and fibers along the interface so good interfacial bonding is important to achieve optimum reinforcement. It is possible to have an strong interface enabling crack propagation which can reduce toughness and strength. But for plant based fiber composites there is low interaction between the hydrophilic fibers and matrices which leads to poor interfacial bonding. [21].. Electrostatic bonding only has great influence for metallic interfaces. Chemical bonding occurs when chemical groups on the fiber surface and in the matrix react to form bonds. Better chemical bonding can be obtained through by using coupling agent that acts as a bridge between the fiber and matrix.

FABRICATION PROCESS Commonly methods used for NFC are extrusion, injection molding and compression molding. Resin transfer molding is mainly used with thermoset matrices and pultrusion which has been employed for combined flax /PP yarn composites and thermoset matrix composites [22]. Different factors affecting properties are temperature, pressure and speed of processing. Fabricating composite at high temperate can degrade fiber properties, which limits the thermoplastic matrices used to those with melting points lower than the fiber degradation temperature. In extrusion thermoplastic in the form of beads or pellets, is softened and mixed with the fiber transported by means of a single or two rotating screws, compressed and allowed to come out of the chamber at a steady rate through a die. High screw speed can result in air entrapment, excessive melt temperatures and fiber breakage. Low speeds lead to poor mixing and improper wetting of the fibers. Twin screw systems have been utilized to give better dispersion of fibers and better mechanical performance than single screw extruders [23]. Compression molding is used for thermoplastic matrices with loose chopped fiber or mats of short or long fiber either randomly oriented. The fibers are normally packed alternately with thermoplastic matrix sheets before pressure and heat are applied. The viscosity of the matrix during pressing and heating should be carefully controlled. Good quality composites can be produced by controlling viscosity, pressure, holding time, temperature taking account of the type of fiber and matrix [24].

CONCLUSION

Natural fiber composite are getting attention of researcher in current scenario of developing new materials. So there is need to find the natural fibers and find out their potential. There are different extraction and processing techniques to fabricate natural fiber composites. In order to prepare a good quality composite we should find out the all factors influencing the mechanical performance of composite material. Also it has been concluded that selection of proper fabrication process is necessary to impart good mechanical properties. Natural fibers should be properly chemically treated before adding them in selected polymer matrix.

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